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Datasheet for the decision of 14 November 2022

Case Number: T 3084/19 - 3.5.02

Application Number: 11807435.0

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Language of the proceedings: EN

Title of invention:
Power converter circuits including high electron mobility transistors for switching and rectification

Applicant:
Wolfspeed, Inc.

Relevant legal provisions:
EPC Art. 56, 123(2)

Keyword:
Inventive step - main request and third auxiliary request (no)
Amendments - first and second auxiliary requests - extension beyond the content of the application as filed (yes)

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Case Number: T 3084/19 - 3.5.02

D E C I S I O N
of Technical Board of Appeal 3.5.02
of 14 November 2022

Appellant: (Applicant)	Wolfspeed, Inc. 4600 Silicon Drive Durham, NC 27703 (US)
Representative:	Boult Wade Tennant LLP Salisbury Square House 8 Salisbury Square London EC4Y 8AP (GB)
Decision under appeal:	**Decision of the Examining Division of the European Patent Office posted on 17 May 2019 refusing European patent application No. 11807435.0 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman	R. Lord
Members:	C.D. Vassoille
	J. Hoppe

Summary of Facts and Submissions

I. This is an appeal of the applicant against the decision of the examining division to refuse European patent application no. 11 807 435.0.

II. The following document is relevant for the present decision:

D1: US 2009/0278513 A1

III. The decision under appeal is a decision according to the state of the file, referring to the communications issued by the examining division on 20 July 2018 and 18 April 2019. In these communications, the examining division had found that the subject-matter of claim 1 of the main request did not involve an inventive step in view of document D1 and that the first auxiliary request contravened the requirement of Article 123(2) EPC.

IV. In a communication under Article 15(1) RPBA 2020, the board informed the appellant that the subject-matter of claim 1 according to each of the main request and the third auxiliary request appeared not to involve an inventive step and that claim 1 of each of the first and second auxiliary requests seemed to violate Article 123(2) EPC.

V. Oral proceedings took place before the board on 14 November 2022 as a videoconference.

The applicant (appellant) requested that the decision under appeal be set aside and that a patent be granted on the basis of the main request, or as an auxiliary

measure on the basis of one of the first to third auxiliary requests, all requests filed with the statement of grounds of appeal.

VI. Claim 1 of the main request reads as follows:

"A power converter circuit (100), comprising:
a storage component (160);
a rectifier component (150) connected to the storage component, comprising a first field effect transistor (202) that is a high voltage depletion mode semiconductor and having first and second bias states and a SiC low voltage hot carrier semiconductor diode (204) having a cathode connected to a source node of the first field effect transistor and an anode connected to a gate node of the first field effect transistor; and
a switch (140) connected to the storage component and the rectifier component, comprising a second field effect transistor having first and second operational states;
wherein the first and second field effect transistors comprise first and second high electron mobility transistors, HEMTs, respectively;
wherein the power converter circuit has a switching frequency in a range of about 10 MHz - 100 MHz when operating in a resonance switched operational mode and in a range of about 1 MHz - 10 MHz when operating in a hard switched operational mode; and
wherein a reverse voltage across the SiC low voltage hot carrier semiconductor diode (204) is limited to a threshold voltage of the first field effect transistor (202)."

VII. Claim 1 of the first auxiliary request differs from claim 1 of the main request in the following additional feature:

"wherein a threshold voltage of the hot carrier semiconductor diode (204) only sustains the threshold voltage of the first field effect transistor (202)"

VIII. Claim 1 of the second auxiliary request differs from claim 1 of the main request in the following additional feature:

"wherein a threshold voltage of the hot carrier semiconductor diode (204) is approximately equal to the threshold voltage of the first field effect transistor (202)"

IX. Claim 1 of the third auxiliary request differs from claim 1 of the main request in the following additional feature:

"wherein the hot carrier semiconductor diode (204) only sustains the threshold voltage of the first field effect transistor (202)"

X. The relevant arguments of the appellant can be summarised as follows:

Main request

The subject-matter of claim 1 of the main request involved an inventive step in view of document D1. The subject-matter of claim 1 differed from the power converter circuit of D1 in particular in the following feature:

"...the power converter has a switching frequency in a range of about 10 MHz - 100 MHz when operating in a resonance switched operational mode, and in a range of about 1 MHz - 10 MHz when operating in a hard switched operational mode"

Reducing the size and weight of the circuit was not the appropriate objective technical problem in view of the distinguishing feature. The appropriate objective technical problem would rather be that of how to provide a high frequency switched mode power converter circuit that could also handle higher voltage levels. The solution of that problem was to operate in a specific range in the hard switched mode and in a different specific range in the resonance switched mode. The skilled person starting from D1 would not come to this solution but rather work in the maximum ranges.

The switching frequencies used in the various operational modes were not merely a matter of obvious design choice. Document D1, did not disclose anything to the skilled person concerning operation of the switch in both a hard switched mode and a soft or resonance switched mode. The ON-OFF transitions at high current and/or voltage levels resulted in switching losses that increased with frequency. Soft or resonance switching, however, referred to timing the ON-OFF transitions of the MOSFET at moments when the voltage or current were at zero. Merely increasing the operation frequency of a circuit would result in significant switching losses when the circuit was operating in a hard switched operational mode. Thus, the frequency ranges specified in claim 1 were those that could result in an efficiency of at least 95% for

both a hard switched mode and a resonance switched mode.

Document D1 did not disclose or even hint at the idea of different operational frequencies being supported for the two different modes, while maintaining an efficiency of at least 95%. Since neither the solution, nor its significant benefits would have been obvious to the skilled person, it was considered that the main request fulfilled the requirements of Article 56 EPC.

First auxiliary request

The skilled person directly and unambiguously understood from paragraph [0051] of the original application (see WO 2012/009410 A1) that it was a feature or aspect of the hot carrier semiconductor diode 204 that sustains the threshold voltage of the depletion mode semiconductor. This was a matter of simple common sense. The issue of added matter under Article 123(2) EPC thus reduced to assessing the question: would the skilled person understand, directly and unambiguously, that it is the threshold voltage of the hot carrier semiconductor diode 204, that sustains the threshold voltage of the depletion mode semiconductor?

In the reverse bias mode, the Schottky diode was reverse biased so that the source node of the depletion mode semiconductor, to which the Schottky diode was connected, was at a floating potential. This in turn led to the depletion mode semiconductor being reverse biased and not conductive. In that case, as was explained in the first part of paragraph [0051], the rectifier 200 did not conduct. It was further stated in the second sentence of paragraph [0051] that "The

reverse voltage across the hot carrier semiconductor diode 204 is limited to the threshold voltage of the depletion mode semiconductor 202".

Hence, although the next but one sentence in that paragraph did not itself state explicitly that it was the threshold voltage of the hot carrier semiconductor diode that sustained the threshold voltage of the depletion mode semiconductor, from the previous discussions, and from the skilled person's understanding of figure 2, this would be immediately and unambiguously derivable.

Second auxiliary request

The alternative form of wording proposed to define the threshold voltage of the hot carrier semiconductor diode (204) relative to the threshold voltage of the first field effect transistor was based on the passages between paragraphs [0048] and [0051], in particular in paragraph [0051] which discussed the reverse bias case of the rectifier 200, in which the hot carrier semiconductor diode and the first field effect transistor were each reverse biased. From this paragraph it was apparent to the skilled reader that the threshold voltage of the hot carrier semiconductor diode was, in this reverse bias mode, approximately equal to the threshold voltage of the first field effect transistor.

Third auxiliary request

The subject-matter of claim 1 of the third auxiliary request involved an inventive step. Document D1 did not disclose or suggest any parameter or characteristic of the Schottky diode 128 which sustained a threshold

voltage of the D-mode III-nitride device 130. Reference D1 merely stated that the Schottky diode 128 could be a low voltage silicon diode and did not provide any description of its threshold voltage other than that it was a low voltage diode.

Reasons for the Decision

1. The appeal is admissible.

2. Main request - Inventive step (Article 56 EPC)

2.1 The subject-matter of claim 1 does not involve an inventive step in view of document D1 in combination with the common general knowledge of the skilled person.

2.2 Document Dl was considered by the examining division to form the prior art closest to the subject-matter of claim 1 and the appellant did not object to this finding. The board also sees no reason to deviate from this.

2.3 Furthermore, the examining division considered the subject-matter of claim 1 of the main request to differ from document Dl *inter alia* in the following features:

(a) an SiC low voltage hot carrier semiconductor diode

(b) the power converter circuit has a switching frequency in a range of about 10 MHz - 100 MHz when operating in a resonance switched operational mode and in a range of about 1 MHz - 10 MHz when operating in a hard switched operational mode

2.4 The appellant did not contest the examining division's finding according to which the distinguishing features do not provide a synergistic effect. Nevertheless, for the sake of completeness, the board confirms this finding of the examining division (see in particular points 3.3 and 3.4 of the communication dated 20 July 2018).

2.5 The appellant concentrated the present appeal on the question of whether distinguishing feature (b) involves an inventive step in view of document D1.

2.6 The appellant argued that the objective technical problem, when starting from document D1 and in view of the distinguishing feature (b), was that of how to provide a high frequency switched mode power converter circuit that can also handle higher voltage levels.

2.7 Even taking into account the objective technical problem as suggested by the appellant, the board has arrived at the conclusion that the subject-matter of claim 1 does not involve an inventive step.

2.8 The appellant did not contest that a hard switched mode and a resonance switched mode are well known modes of operation in the prior art in connection with the power converter circuits in question. Document D1 indeed does not explicitly disclose a specific mode of operation. However, it is clear that the circuit of D1 necessarily operates in an operational mode, be it in the resonance switched mode or the hard switched mode.

2.9 The skilled person when being confronted with the objective technical problem of how to provide a high frequency switched mode power converter circuit that can also handle higher voltage levels, would forcibly

need to select an appropriate operational frequency range for the used mode of operation (resonance or hard switched).

2.10 Document Dl already provides, especially in the light of the disclosure in paragraph [0025], a suggestion to operate the power converter circuit at higher frequencies. There cannot be any doubt that the skilled person understands this teaching in connection with the respective operation mode, even if this is not explicitly mentioned in D1. In particular, it pertains to the skilled person's common general knowledge that different modes of operation require different frequency ranges to operate the circuit efficiently at higher voltage levels.

2.11 Furthermore, it is true that the specifically claimed frequency ranges of 10 MHz to 100 MHz for the resonance switched operational mode and 1 MHz to 10 MHz for the hard switched operational mode, are not explicitly mentioned in document D1. However, the board is not convinced that the specifically claimed frequency ranges provide any special technical effect and thus, confirms the corresponding finding of the examining division in the communication of 20 July 2018, point 3.5.2.

The only disclosure in the description regarding the claimed frequency ranges can be found in paragraph [0056], where the following is stated:

> "Moreover, the low capacitance of the switching and rectification components may allow the power converter circuit to operate at frequencies in a range of approximately 10 MHz to 100 MHz in a resonance switched operational mode and 1 MHz to 10

MHz in a hard switched operational mode while maintaining an efficiency of at least 95%."

The description does not describe why the mentioned frequency ranges, as claimed in claim 1 of the main request, achieve a particular advantage for the modes of operation in question. Therefore, the corresponding selection cannot be considered as going beyond an ordinary choice which the skilled person would have made in view of the different technical particularities of the modes of operation, without any inventive step being involved.

2.12 In particular, the board is convinced that the relationship between different operation modes, the frequency ranges adapted for each operational mode as well as the efficiency in relation to the voltage to be handled is known to the skilled person from the common general knowledge.

Thus, in view of the teaching of D1, i.e. driving the circuit with an increased operating frequency and an increased efficiency (see for example paragraphs [0014] and [0021]), the claimed frequency ranges must be considered as obvious choices, depending on the respective type of mode of operation of the power converter circuit, that the skilled person would select in order to provide a high frequency switched mode power converter circuit that can also handle higher voltage levels.

2.13 Therefore, the examining division was right to conclude that the subject-matter of claim 1 is rendered obvious by document D1.

In conclusion, the subject-matter of claim 1 of the main request does not involve an inventive step in the sense of Article 56 EPC.

3. First auxiliary request - Amendments (Article 123(2) EPC

3.1 Claim 1 of the first auxiliary request extends beyond the content of the application as originally filed.

3.2 Claim 1 of the first auxiliary request comprises the following additional feature:

> "wherein a threshold voltage of the hot carrier semiconductor diode (204) only sustains the threshold voltage of the first field effect transistor (202)" (emphasis added by the board)

3.3 The appellant particularly relies on paragraph [0051] of the original application (see the international publication no. WO 2012/009410 A1) as a basis for the amendment of claim 1 of the first auxiliary request. However, this paragraph merely discloses the following:

> "the hot carrier semiconductor diode 204 need only sustain the threshold voltage of the depletion mode semiconductor".

No mention of "a threshold voltage" of the hot carrier semiconductor diode is contained in this paragraph. In particular, no explicit information is present in this paragraph that it is the threshold voltage of the hot carrier semiconductor diode that sustains the threshold voltage of the field effect transistor.

3.4 According to the EPC, an amendment can only be made within the limits of what a skilled person would derive directly and unambiguously, using common general knowledge, and seen objectively and relative to the date of filing, from the whole of the documents as filed (see decisions of the Enlarged Board of Appeal G 3/89 and G 11/91, referring to this test as "gold standard").

3.5 The board has arrived at the conclusion that it cannot be directly and unambiguously, either explicitly or implicitly, derived from the original application that it is the threshold voltage of the hot carrier semiconductor diode that sustains the threshold voltage of the depletion mode semiconductor (first field effect transistor).

3.6 The appellant particularly pointed to the disclosure in the original application in paragraphs [0048] to [0051], which provide a description of the power converter circuit in a forward bias mode and in a reverse bias mode. The appellant further explained that according to the description in paragraph [0051], the reverse voltage across the hot carrier semiconductor diode is limited to the threshold voltage of the depletion mode semiconductor. The appellant concluded from the explanations in the original application that it would be the skilled person's direct and unambiguous understanding of figure 2 and paragraph [0051] that it is the threshold voltage of the hot carrier semiconductor diode that sustains the threshold voltage of the first field effect transistor.

3.7 The board cannot draw a corresponding conclusion either in the light of figure 2 or the corresponding description of the operation of the device.

It is evident that the reverse voltage across the hot carrier semiconductor diode may be limited to the threshold voltage of the depletion mode semiconductor, as described in paragraph [0051] and as recited in claim 1. As explained in paragraph [0050] of the original application, if the gate to source voltage falls below the threshold voltage of the depletion mode semiconductor, this device may be in a non-conducting state. In other words, this condition is met, if the (reverse) voltage falling on the hot carrier semiconductor diode becomes lower then the threshold voltage of the depletion mode semiconductor.

3.8 In the context of hot carrier semiconductor diodes, the skilled person would normally understand the threshold voltage of such a diode to refer to a forward threshold voltage. Correspondingly, as explained in paragraphs [0048] and [0049] of the application, a slight forward bias is applied to the depletion mode semiconductor gate to source junction in the forward bias case. Thereupon, the depletion mode semiconductor becomes conductive.

3.9 Consequently, it might be true in principle, that it is sufficient for the hot carrier semiconductor diode to have a threshold voltage that substantially corresponds to the threshold voltage of the depletion mode semiconductor, such as to keep the field effect transistor in a conductive state with only a low forward voltage drop across the resulting diode. This interpretation of the respective passage in paragraph [0051] of the original application, however, does not constitute an implicit disclosure that the skilled person would directly and unambiguously derive from the application.

3.10 Rather, what the skilled person would understand directly and unambiguously from paragraph [0051] in connection with the embodiment illustrated in figure 2 of the application, is nothing more than that the hot carrier semiconductor diode has only to sustain the threshold voltage of the depletion mode semiconductor. In other words, it is sufficient if a voltage dropping across the hot carrier semiconductor diode sustains the threshold voltage of the depletion mode semiconductor. This is however not equivalent to the technical feature that it is (precisely) the threshold voltage of the hot carrier semiconductor diode that sustains the threshold voltage of the depletion mode semiconductor.

3.11 The appellant's explanations, even if they might be a possible interpretation, are therefore not sufficient for the amendment to meet the requirement of Article 123(2) EPC.

4. Second auxiliary request - Amendments (Article 123(2) EPC

4.1 Claim 1 of the second auxiliary request extends beyond the content of the application as originally filed.

4.2 Claim 1 of the second auxiliary request comprises the following additional feature:

> "wherein a threshold voltage of the hot carrier semiconductor diode (204) is approximately equal to the threshold voltage of the first field effect transistor (202)"

4.3 Corresponding to the first auxiliary request, the appellant essentially relies on paragraph [0051] of the

original application as a basis for the amendment of claim 1 of the second auxiliary request.

4.4 For the reasons set out under points 3.4 to 3.11 above with respect to the first auxiliary request, claim 1 of the second auxiliary request contravenes the requirement of Article 123(2) EPC.

In particular, as set out under point 3.10 above, the skilled person might understand from paragraph [0051] of the original application that is sufficient if a voltage dropping across the hot carrier semiconductor diode sustains the threshold voltage of the depletion mode semiconductor. This is however not equivalent to the technical feature that the threshold voltage of the hot carrier semiconductor diode is approximately equal to the threshold voltage of the first field effect transistor (depletion mode semiconductor).

Therefore, also the amendment of claim 1 of the second auxiliary request extends beyond the content of the application as originally filed and thus contravenes the requirement of Article 123(2) EPC.

4.5 Given that claim 1 of the second auxiliary request clearly contravenes the requirement of Article 123(2) EPC, the question of admittance of the second auxiliary request into the appeal procedure according to Article 12(4) RPBA 2007 (Article 25(2) RPBA 2020) could be left open.

5. Third auxiliary request - Inventive step (Article 56 EPC)

5.1 The subject-matter of claim 1 of the third auxiliary request does not involve an inventive step in view of

document D1 in combination with the common general knowledge of the skilled person.

5.2 Document D1 was considered to form the prior art closest to the subject-matter of claim 1, and the appellant did not object to this.

5.3 Claim 1 of the third auxiliary request differs from claim 1 of the main request in the following additional feature:

> "wherein the hot carrier semiconductor diode (204) only sustains the threshold voltage of the first field effect transistor (202)"

5.4 Furthermore, there is no synergistic effect between the additional feature of claim 1 of the third auxiliary request and the further distinguishing features of claim 1 of the main request with regard to document D1, as set out under point 2.3 above. In the present case, therefore, only the question of whether the additional feature of claim 1 of the third auxiliary request is rendered obvious in the light of document D1 was to be assessed.

5.5 It was not contested by the appellant, that document D1 discloses a rectifier component as recited in claim 1 (except the use of a SiC diode). Furthermore, the operation of the rectifier component including the hot carrier semiconductor diode (Schottky diode 128) and the field effect transistor (D-mode III-nitride device 130) corresponds to the operation of the claimed rectifier component, see D1 in particular paragraphs [0020] and [0021].

5.6 Document D1 does not explicitly disclose that the hot carrier semiconductor diode only sustains the threshold voltage of the field-effect transistor.

However, the person skilled in the art normally strives to keep the dimensioning of the circuit components as small as possible and would therefore always aim for a solution which requires the least structural effort. It would therefore have been obvious for a person skilled in the art to use a SiC low-voltage hot carrier semiconductor diode that only sustains the threshold voltage of the transistor.

5.7 The appellant's main argument presented in favour of an inventive step of the subject-matter of claim 1 of the third auxiliary request in view of document D1 was that D1 did not disclose or suggest any parameter or characteristic of the Schottky diode which sustains a threshold voltage of the D-mode III-nitride device (corresponding to the first field effect transistor in the sense of claim 1). While this is true in principle, as discussed above, the skilled person when dimensioning the components of the rectifier component of D1, would readily have concluded that the Schottky diode, i.e. the hot carrier semiconductor diode, only has to sustain the threshold voltage of the field effect transistor in order to function properly. It is also evident that the skilled person would know what the threshold voltage of a field effect transistor is or at least how to determine it. The latter was not contested by the appellant.

This is also not contradicted by the fact that, as the appellant submitted, in particular in paragraph [0021] of D1 a reduced charge storage of the rectifier component is described to be advantageous.

Consequently, even though document D1 does not explicitly disclose that the hot carrier semiconductor diode only sustains the threshold voltage of the first field effect transistor, this feature is considered to be obvious to the skilled person. The board thus arrived at the conclusion that the subject-matter of claim 1 of the third auxiliary request does not involve an inventive step in the sense of Article 56 EPC.

5.8 Given that claim 1 of the third auxiliary request does not involve an inventive step in the sense of Article 56 EPC, the question of admittance of the third auxiliary request into the appeal procedure according to Article 12(4) RPBA 2007 (Article 25(2) RPBA 2020) could be left open.

6. Result

Given that the subject-matter of claim 1 of the main request and of the third auxiliary request does not involve an inventive step and that claim 1 of each of the first and second auxiliary requests contravenes Article 123(2) EPC, the appeal had to be dismissed.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

U. Bultmann R. Lord

Decision electronically authenticated